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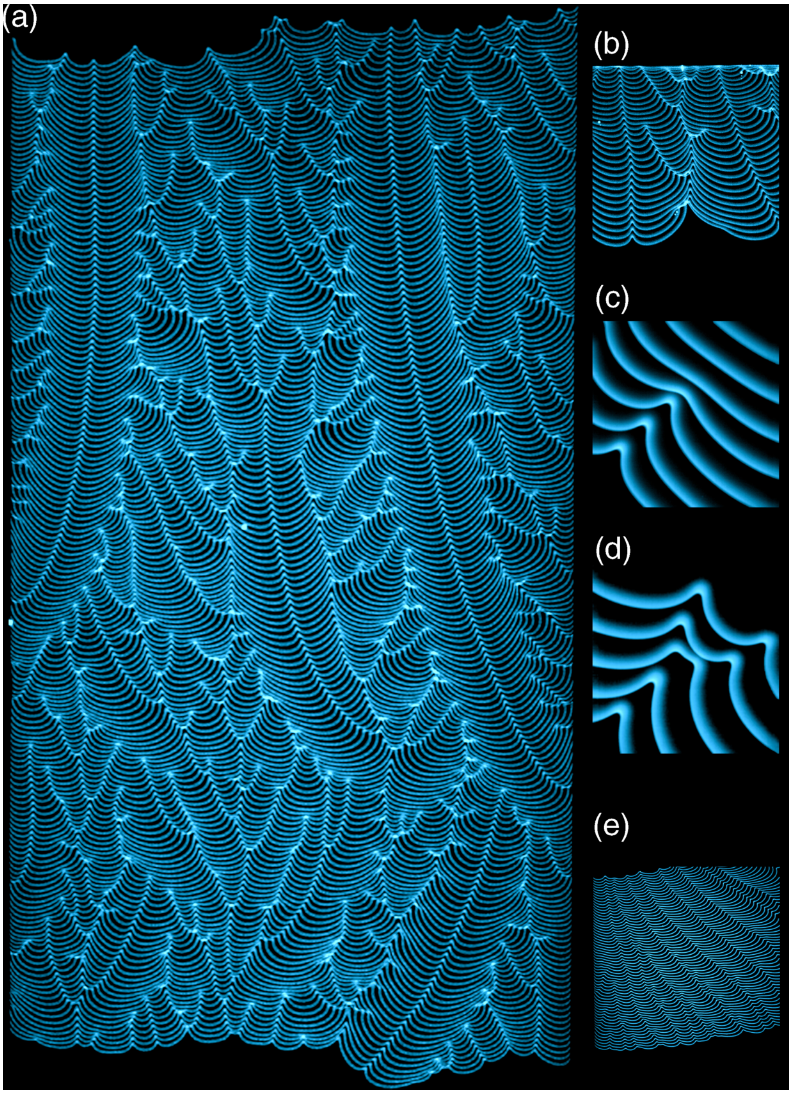

FIG. 1. (a) Downward propagation of a stoichiometric premixed propane air flame in a vertically oriented Hele-Shaw cell. (b) Destabilization of a flat initial condition. (c) Cusp creation. (d) Cusps merging. (e) Lean flame close to the stability threshold. http://dx.doi.org/10.1103/APS.DFD.2014.GFM.P0036.

Experimental two dimensional cellular flames

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Premixed flames, where fuel and oxidizer are mixed prior to combustion, are widely used in gas turbines or internal combustion engines like spark ignition engines since they provide a practical mean to control the rate of combustion and lead generally to lower pollutant emissions, particularly for lean flames. However, thermal and hydrodynamical effects distort inherently the flame front, which generically presents a collection of cells, separated by cusps, merging and birthing at random and having a broad distribution of sizes. Studying this wrinkling in the flamelet regime, for low turbulent velocities not influencing the inner structure of the flame, is of prime importance as it rules the global velocity of the flame, an information also useful for calibrating numerical simulations.[1]

The description of the flame propagation and its dynamics is difficult in usual cases, such as propagation in cylindrical tubes[2] and deserves a dedicated experimental facility allowing for quantitative imaging. For this purpose, a vertically oriented Hele-Shaw cell (two glass plates separated by a thin gap of 5 mm, 50 cm wide, and 150 cm in height) has been used. It is filled with a mixture of propane and air which is ignited at the top of the cell. The propagation of the flame along the cell in a quasi two-dimensional fashion allows for the precise analysis of its corrugations from the wrinkling of an initially flat flame front (Fig. 1(b)) to the steady wrinkled regime (Fig. 1(a)). The corresponding space-time diagrams illustrating the cusps dynamics have been obtained for stoichiometric propane air flames, diluted with nitrogen in the second case. They are constructed by superimposing the pictures of the front taken with a high speed camera at successive instants of times. The fields of view are, respectively, 12 cm wide and 50 cm wide. The frame rates are, respectively, 100 images/s and 60 images/s.

The key elements for understanding the statistical features of the front are the formation (Fig. 1(c)) and merging (Fig. 1(d)) of the cusps. These two concomitant and competing processes rule the distribution of the sizes of the cells, a distribution which appears to be identical for a large variety of gas mixture provided that the flame is unstable enough, i.e., not too close from the stability threshold. In that later case, most of the cells have the same size, as seen in Fig. 1(e) (equivalence ratio 0.66, field of view 43 cm wide, and recorded at 25 fps).

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